

EPA & NANOTECHNOLOGY: STRATEGY, RESPONSIBILITY AND ACTIVITIES

Nora Savage, PhD

**US EPA,
Office of Research & Development
National Center for Environmental
Research
Environmental Engineering Research
Division**

April 7, 2006

OUTLINE

- NNI Structure and Activities
- EPA Strategies and Activities
- EPA-sponsored Research
- Looking Forward



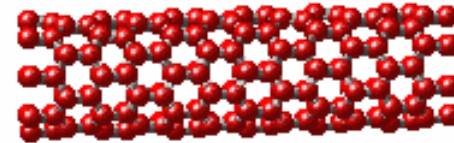
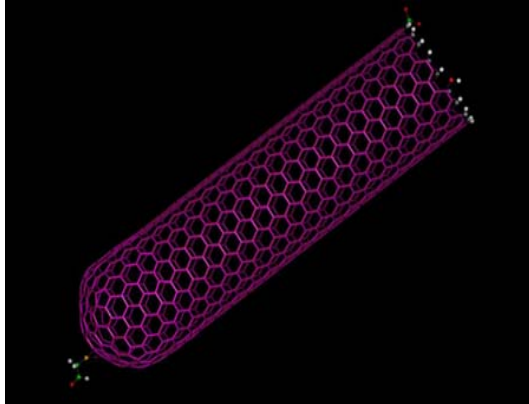
National Nanotechnology Initiative

EPA is a member of the subcommittee - Nanoscale Science, Engineering and Technology

- **Federal agencies and departments that participate in NNI**
- **Established in 2001**
- **Responsible for coordinating federal government's nanoscale research and development programs**
- **National Nanotechnology Coordinating Office (NNCO) – secretariat, point of contact**

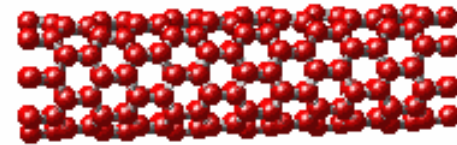
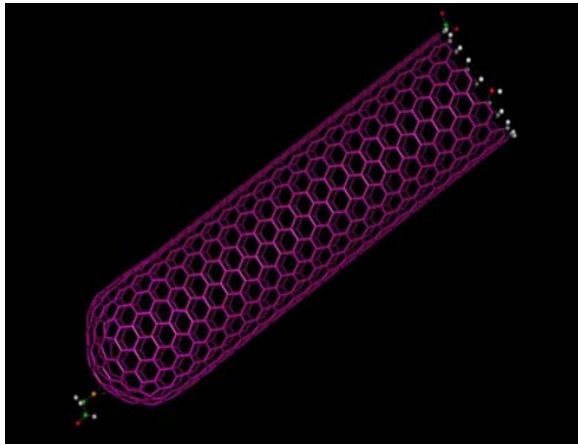


Definition of Nanotechnology?



- The ability to extract large sums of money from a decreasing federal research budget?
- The development of novel properties for any business with “nano” prefix?
- The capacity to manipulate at the nano level to multiply exponentially the number of nano meetings?

NNI Definition of Nanotechnology



- The understanding and control of matter at dimensions of roughly 1 to 100 nanometers;
- Where unique phenomena enable novel application

Congress

White House/OSTP

OMB

PCAST

Nano Health and Environ.
Impacts (NEHI)

Nano Innovation and
Industry Liaison (NIIL)

Nano Public Engagement
Group (NPEG)

Global Issues In
Nanotechnology
(GIN)

Nanoscale Science, Engineering and
Technology Subcommittee

Independent Agencies

CPSC, EPA, FDA, ITIC,
NASA, NIH, NIOSH, NIST,
NRC, NSF, OMB, OSHA

Departments

DHS, DHHS, DOC/PTO,
DOD, DOE, DOJ, DOS, DOT.
DOTreas, USDA



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Unique Properties of Nanoscale Materials

- Chemical reactivity of nanoscale materials greatly different from more macroscopic form, e.g., gold
- Vastly increased surface area per unit mass, e.g., upwards of 100 m² per gram
- Quantum size effects result in unique mechanical, electronic, photonic, and magnetic properties of nanoscale materials
- New chemical forms of common chemical elements, e.g., fullerenes, nanotubes of carbon, titanium oxide, zinc oxide, other layered compounds



Topics Being Addressed by NEHI WG

- Nomenclature for identifying and delineating nanomaterials
 - Nanomaterials of same chemical but having different forms
 - E.g., carbon black, diamond, buckyball, nanotube
 - Nanomaterials of same chemical but differing only by physical size
 - E.g., TiO_2 , quantum dots (CdS or CdSe)
 - ANSI-Nanotechnology Standards Panel formed
- Documentation of “recommended practices” for working with the nanomaterials
 - Documentation being developed by NIOSH & OSHA
 - Q&As and “Current Intelligence Bulletin” to be forthcoming
- Data on potential toxicity of nanomaterials
- Strategic plan for guiding research – under development



NNI Environment, Health and Safety Research

NSF	Basic research: environmental effects of nanoparticles; nanoparticles in air pollution; water purification; nanoscale processes in the environment
EPA	Toxicology of manufactured nanomaterials; Fate, transport, & transformation; Human exposure and bioavailability
DoD	Physicochemical characteristics & toxicological properties of nanomaterials computational model that will predict toxic, salutary and biocompatible effects based on nanostructured features
NTP	Potential toxicity of nanomaterials, titanium dioxide, several types of quantum dots, & fullerenes
DoE	Transport & transformation of nanoparticles in the environment, exposure & risk analysis; Health effects
NIH	Nanomaterials in the body, cell cultures, and laboratory use for diagnostic and research tools
NIST	Developing measurement tools, tests, and analytical methods



Please check out the NNI Website

www.nano.gov

NNCO working to provide access to:

- News on NNI activities, workshops, and reports
- Latest news on nanotechnology - subscription to listserve with daily updates
- Ongoing announcements of solicitations
- Up-to-date reporting of nanotechnology workshops and conferences
- Information for educators - K12 to post graduate



THE NATIONAL NANOTECHNOLOGY INITIATIVE

*Research and Development Leading to a Revolution
in Technology and Industry*

Supplement to the President's FY 2006 Budget



THE NATIONAL NANOTECHNOLOGY INITIATIVE

STRATEGIC PLAN

Developed by the Nanoscale Science, Engineering
and Technology Subcommittee

Committee on Technology
National Science and Technology Council

December 2004



Available on web at:

<http://www.nano.gov>



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Small Times Study of Nano “Industry”

- Commissioned by NNI
- Nanotechnology Companies and Organizations in the United States
 - Headquartered in US or with major business activity in US
- Identified companies, organizations and agencies complying with strict selection criteria
- Identified new jobs in nano "pure plays" – that is, companies for whom nanotechnology R&D, manufacturing, and applications is a sole focus
- Identified nano products



Companies with something in common



Display Screens
Motorola (NTs)



Cars - Hummer
GM (Nanocomposites)



Nano SilverSeal
Refrigerator
Samsung (nanoparticle-coated)



Tennis Rackets
Wilson (C fibers)

Nano-Products on the Market Now



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Companies with something in common



Shemen Industries

canola oil by NutraLease, an Israeli startup, using 30 nm capsules



Nano-Care fabric

wrinkle-resistant, stain-repellent

(Eddie Bauer, Lee, Old Navy, Tiger Woods, Bass, Nike) Nano-Tex



Plenitude Revitalift

Loreal

EPA's Mission:



To protect human health and the environment



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EPA's Interest in Nanotechnology

- **Promise for environmental protection**

Cleaning up *past* environmental problems

Improving *present* processes

Preventing *future* environmental problems

- **Potential harmful effects to human health or the environment**

- **Regulatory responsibilities**

- **Consideration of environmental benefits and impacts from the beginning, as new technologies develop**



International Activities

Organization for Economic Co-operation and Development

- Workshop on the Safety of Manufactured Nanomaterials (hosted by U.S., 7-9 Dec 2005, Washington, DC) for potential Nano Working Group
 - Definitions, nomenclature and characterization
 - Environmental, human health effects
 - Regulatory frameworks
- Output of Workshop presented at the 39th meeting of the Chemicals Committee (February 2006)
- Also Potential Working Party in Committee on Science & Technology Policy (CSTP)

American National Standards Institute

- Nanotechnology Standards Panel (NSP) formed - August of 2004
- Priority recommendations for nanotechnology standardization needs published - November of 2004



The Organisation for Economic Co-operation and Development (OECD)

Workshop on the Safety of Manufactured Nanomaterials

(Dec. 7-9, 2005, Washington, DC)

- Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides, and Biotechnology
- 4 themes:
 - **Definitions, nomenclature and characterisation**
 - **Environmental effects**
 - **Human health effects**
 - **Regulatory frameworks**
- Attendance was limited
- Output of Workshop to be presented at the 39th meeting of the Chemicals Committee (February 2006)



EPA's National Activities

SPC White Paper

- Science Policy Council (SPC): venue for discussion and management of cross-agency science issues
- **Cross-agency Nanotechnology Workgroup** convened by SPC Dec. 2004
- Group charge: develop a white paper to examine the implications and applications of nanotechnology for the consideration of Agency managers
- Open for public comment from Dec. 2005 through March 2006
- Peer Review Meeting
 - April 19 and 20, 2006, at the Marriott at Metro Center in Washington, DC.
 - two day public meeting
 - To attend the meeting, register by April 15, 2006, by visiting <http://epa.versar.com/nanotech> or by contacting Mr. Andrew Oravetz of Versar, Inc., 6850 Versar Center, Springfield, VA, 22151, 703-642-6832, Aoravetz@versar.com
- Anticipate **Final Document middle of 2006**



EPA White Paper - Contents

- Examination of applications and implications of nanotechnology
- Discussion of science issues across-media and across-EPA statutes
- Recommendations for Agency
- Pollution Prevention and Stewardship
- Research
 - chemical identification and characterization
 - environmental fate
 - environmental detection and analysis
 - potential releases and human exposures
 - human health effects assessment
 - ecological effects assessment
- Risk Assessment
- Cross-Agency Workgroup
- Collaboration
- Training



Extramural Research at EPA

Applications address existing environmental problems, or prevent future problems

(Approx. \$15.6 M to date)

Implications address the interactions of nanomaterials with the environment, and any possible risks that may be posed by nanotechnology

(Approx. \$10.2 million to date, excluding ultrafine)



2005 STAR Solicitation

Environmental and Human Health Effects of Nanomaterials

- Joint with National Science Foundation (NSF), National Institute for Occupational Safety and Health (NIOSH), National Institute of Environmental Health Sciences (NIEHS)
- Dates December 20, 2005 – February 22, 2006
- Approximately \$8 M



2005 GRO Solicitation

Environmentally Benign Manufacturing and Processing

- For under-funded institutions ($< \$35$ M/yr)
- Opens – November 2, 2005 - Closes January 21, 2005
- ~ 2 Million
- Nano option



2006 STAR Solicitation

Environmental and Human Health Effects of Nanomaterials

- Joint with National Science Foundation (NSF), National Institute for Occupational Safety and Health (NIOSH), National Institute of Environmental Health Sciences (NIEHS) and the European Commission
- Anticipated Opening Date – Fall 2006

2006 GRO Solicitation

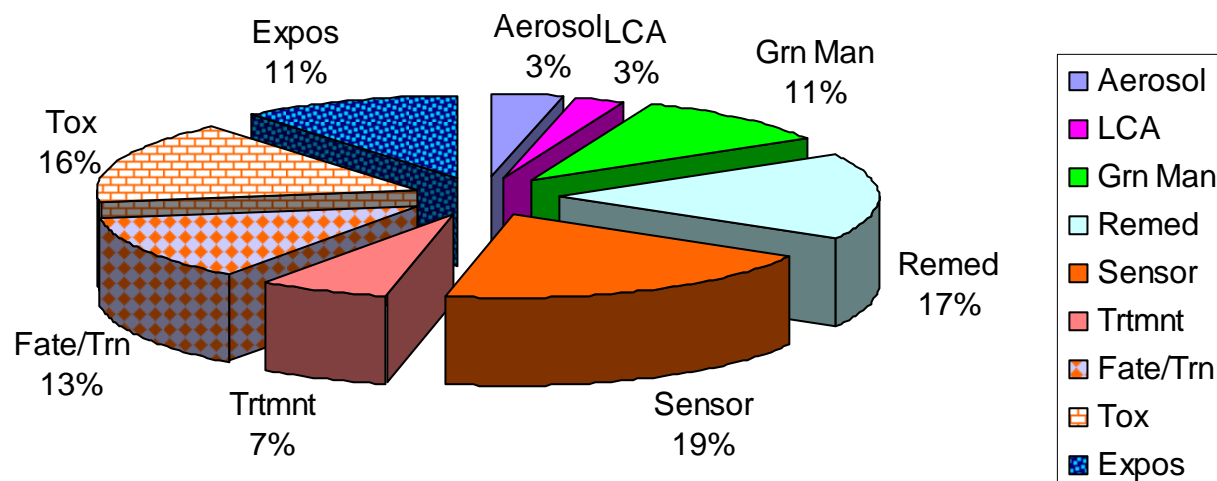
Environmental Applications of Nanomaterials

- Joint with National University of Singapore (NUS)
- Anticipated Opening Date – Fall 2006



NCER Nanotechnology Grantees

STAR & GRO Nano Grants - Applications & Implications



N = 65 Grantees



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Nanotechnology - Possibility for Environmental Benefit

- Improved monitoring & detection capabilities
- **Ultra-Green** manufacturing and chemical processing – eliminate toxic constituents
- Waste-minimization via designed-in pollution prevention at the source - less material to dispose of, atom-by-atom construction
- Reduced energy usage
- Commercially-viable alternative clean energy sources (fuel cells, solar, wind)
- Inexpensive, rapid remediation and treatment technologies
- Sustainability



STAR Implications Research Grants Awarded in 2004-2005

Research Category	Number of Grants ¹	Award Totals
Aerosol	2	\$790,000
Exposure Assessment	9	\$2,515,594
Fate and Transport	9	\$2,881,020
Life-cycle analysis	3 ²	\$574,741
Toxicity	11	\$3,644,505
Total	32	\$10,405,860

¹Two studies supported by the National Institute of Occupational Safety and Health NIOSH, three studies supported by the National Science Foundation (NSF)

²Grant included Fate and transport and exposure assessment



Exposure and Toxicity

Material Class Study Focus	Carbon nanotubes	Fullerenes	Metals	Other ¹
Cytotoxicity	XXXX	X	XXX	XX
Dermal		X	XX	
General toxicity	XXX	X	XXXX	XX
Pulmonary	XXXX	X	XXX	
Translocation/Disposition	X	X	XXX	

¹Other compounds include fibers, dendrimers, quantum dots (if specified as QD)

²Includes LCA studies



Environmental Fate and Toxicity

Material Class Study Focus	Carbon nanotubes	Fullerenes	Metals	Other ¹
Aquatic fate	xxx	xx	xx	
Environmental toxicity	xxx	xx	xxxx	x
Fate in air	x	x	x	xx
Fate in soils/sediment	xxx	xxx	xx	x
Cross media fate/transport ²	xx	xxx	xxx	xx

¹Other compounds include fibers, dendrimers, quantum dots (if specified as QD)

²Includes LCA studies



Human Exposure and Toxicity Studies

Study Focus	Examples of specific effects investigated	Nanomaterials Tested
Cytotoxicity	Affinity to cell membranes, oxidative damage, structure-function relationships, mechanisms	aluminum oxide (Al_2O_3), cerium oxide (CeO_2), cupric oxide (CuO) dendrimers, iron oxide (Fe_2O_3), nickel oxide (NiO), silicon dioxide (SiO_2), titanium dioxide (TiO_2), zinc oxide (ZnO)
Dermal toxicity	Dermal absorption, cutaneous toxicity,	cadmium selenide (CdSe), fullerenes, iron (Fe)
General toxicity	Human blood coagulation, induction of inflammatory gene expression, genotoxicity	aluminum oxide (Al_2O_3), cadmium selenide (CdSe), cadmium telluride (CdTe) dendrimers, fullerenes, gallium nitride (GaN)Geranium, lead selenide (PbSe), nanofibers, nanowires, quantum dots, silicon dioxide (SiO_2), quantum dots, titanium dioxide (TiO_2), zinc sulfide (ZnS)
Pulmonary toxicity	Oxidative stress, inflammation, surface coating effects, nano/non-nano effects, new/aged agglomerated effects, clearance mechanisms	aluminum oxide (Al_2O_3), cerium oxide (CeO_2), cupric oxide (CuO) dendrimers, gold (Au), iron oxide (Fe_2O_3), multiwalled nanotubes (MWNT), nickel oxide (NiO), silicon dioxide (SiO_2), single walled nanotubes (SWNT), silver (Ag), titanium dioxide (TiO_2), zinc oxide (ZnO)
Translocation/Disposition	Translocation to sites distant from original exposure, persistence in vivo.	aluminum oxide (Al_2O_3), iron oxide (Fe_2O_3), titanium dioxide (TiO_2), silicon dioxide (SiO_2), zinc oxide (ZnO)



Environmental Fate/Transport and Environmental Toxicity

Study focus	Examples of specific effects investigated	Nanomaterials Tested
Aquatic fate	Impact on water migration through soil, chemical behavior in estuarine systems, fate in potable water, uptake by aquatic organisms	alumina, magnetite, nanofibers, silicon carbide, silicon dioxide (SiO ₂), single walled nanotubes (SWNT), titanium dioxide (TiO ₂), zinc oxide (ZnO)
Environmental toxicity	Microbial biomass, organic carbon assimilation rates, deposit feeding, uptake, estuarine invertebrates, toxicity in drinking water, fish, frogs, bacteria, fungi, daphnia, algae	cadmium celenide (CdSe), cupric oxide (CuO), iron oxide (Fe ₂ O ₃), molybdenum disulfide (MoS ₂), nanofibers, quantum dots, silicon dioxide (SiO ₂), single walled nanotubes (SWNT), titanium dioxide (TiO ₂), zinc oxide (ZnO)
Fate in air	Emission minimization, sampling and analysis, nucleation rate	fullerenes, silicon dioxide (SiO ₂), single walled nanotubes (SWNT) sulphuric acid (H ₂ SO ₄)
Fate in soils/sediment	Desorption and release from nanoparticle surfaces, disposition of contaminants,	aluminum oxide (Al ₂ O ₃), cadmium celenide (CdSe), hydroxylated fullerenes, magnetite
Cross media fate/Transport	Effects of oxygen, chlorine, UV light	carbon nanofibers, fullerenes, titanium dioxide (TiO ₂), zinc oxide (ZnO)



STAR Grant Publications

- Approximately 55 papers have been produced from researchers funded by STAR grants.
 - 31 papers published, in press or submitted to peer-reviewed journals
 - 4 papers in preparation for submission to a journal
 - 20 papers published in conference proceedings



Nanotechnology - Possibility for Environmental Harm

Human health & Ecosystem Implications:

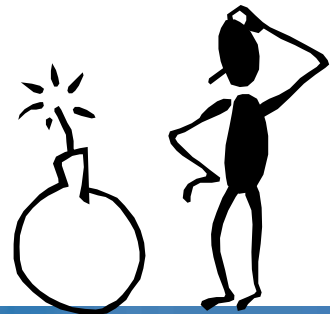
- Potential toxicity, mechanism issues
- Harm to the environment and/or ecosystem through manufacture, use, and/or disposal
- Unknown transport, transformation and fate information of nanomaterials
- Potential bioaccumulation, biotransformation, and bioavailability issues
- Dose/Response



EPA's Regulatory Options



- Use current system?
 - New/Existing chemicals
 - PMNs
 - SNUNs
 - Sections 8(a)/8(d) rules
- Modify current system?
 - Inventory distinction for nano
 - New Inventory
- Develop new system?



EPA's Regulatory Response

- "The Nanoscale Materials Stewardship Program
- OPPT is considering a stewardship program for reporting information pertaining to existing chemicals that are engineered nanoscale materials
- OPPT received input from a public meeting it held in June 2005 and from its FACA, the National Pollution Prevention and Toxics Advisory Committee.
- The program would apply to engineered nanoscale materials in commerce and "soon to enter commerce.
- OPPT is working on an Information Collection Request and a Federal Register notice pertaining to the program



Nanomaterials – Applications & Implications



- Cross blood-brain barrier – drug delivery
- Placed in subsurface areas - remediation
- Small, real-time sensors – detection & protection
- Same compound, different properties – novel uses
- Different disciplines – increased collaboration
- NBIC – myriad possibilities



- Cross blood-brain barrier – impair health
- Placed in subsurface areas – impair ecosystem
- Small, real-time sensors – privacy concerns
- Same compound, different properties – reg. concerns
- Different disciplines – limited understanding
- NBIC – myriad quandaries

EPA Nanotechnology Activities

Building a Green Nanotech Community

Solicitations

2001 RFA - Environmental Applications

2002, 2003 RFA - Environmental Applications and Implications

2003 & 2004 RFA - Health & Ecosystem Effects, Applications

2005 RFA - Health & Ecosystem Effects with NSF, NIEHS, NIOSH

2006 RFA - Health & Ecosystem Effects with NSF, NIEHS, NIOSH and EC and Singapore

Annual SBIR - Nanomaterials 7 Nanotechnology



Workshops

NNI Nanotechnology Grand Challenge in the Environment - May 8-10, 2003

EPA Grantees' Workshop I 2002, Workshop II 2004, Workshop II 2005, Workshop III Oct. 2006

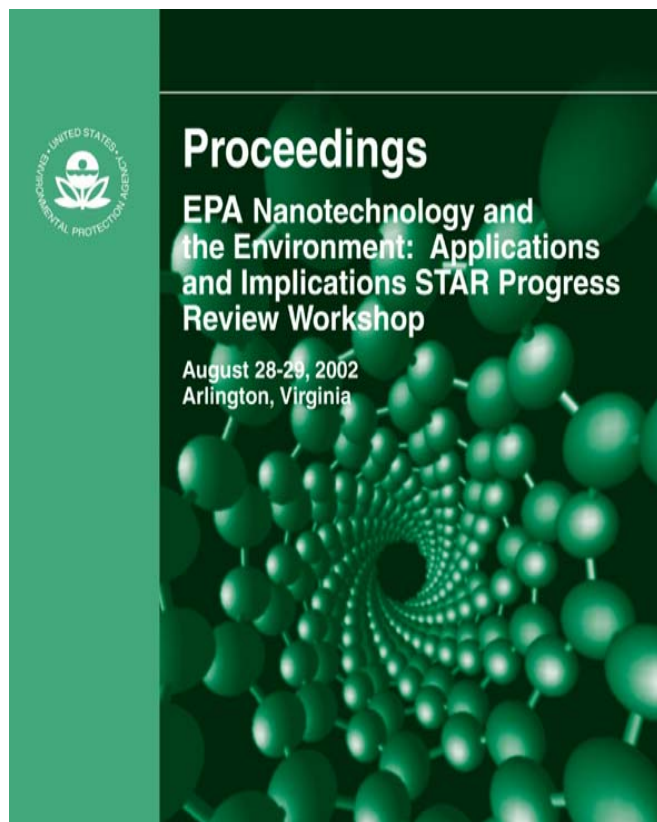
Interagency: Applications and Implications Conference w/ DOC, DOD, DOE, DOT, FDA, NIH, NSF, & USDA - September 2003

Societal Implications II - December 2003

Meetings

ACS, MRS, AIChE, SETAC, AWMA, Woodrow Wilson Center, NAS, ILSI, EC, Canada, Hong Kong, Singapore, Taiwan

STAR Grantees Meeting Proceedings



<http://www.epa.gov/ncer/nano>

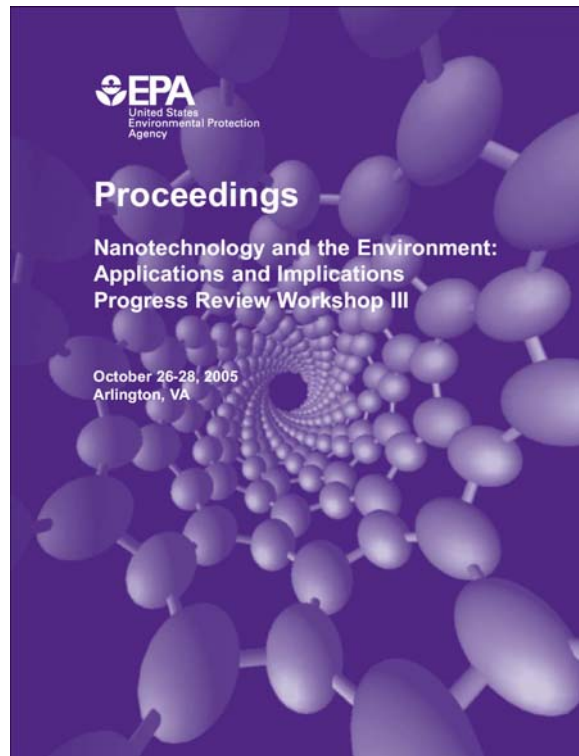


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STAR Grantees Meeting Proceedings

Available in cd format



<http://www.epa.gov/ncer/nano>



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EPA's New Nano Web Page

Nanotechnology Home



Nanotechnology has both applications and implications for the environment. EPA is supporting research in this technology while evaluating its regulatory responsibility to protect the environment and human health. This site highlights EPA's research in nanotechnology and provides useful information on related research at EPA and in other organizations.

www.epa.gov/ncer/nano

Coming Soon EPA-wide Website!!



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Nanotechnology – Environmental Goals

➤ **enable a sustainable future**

&

➤ **usher in a vibrant spring**

